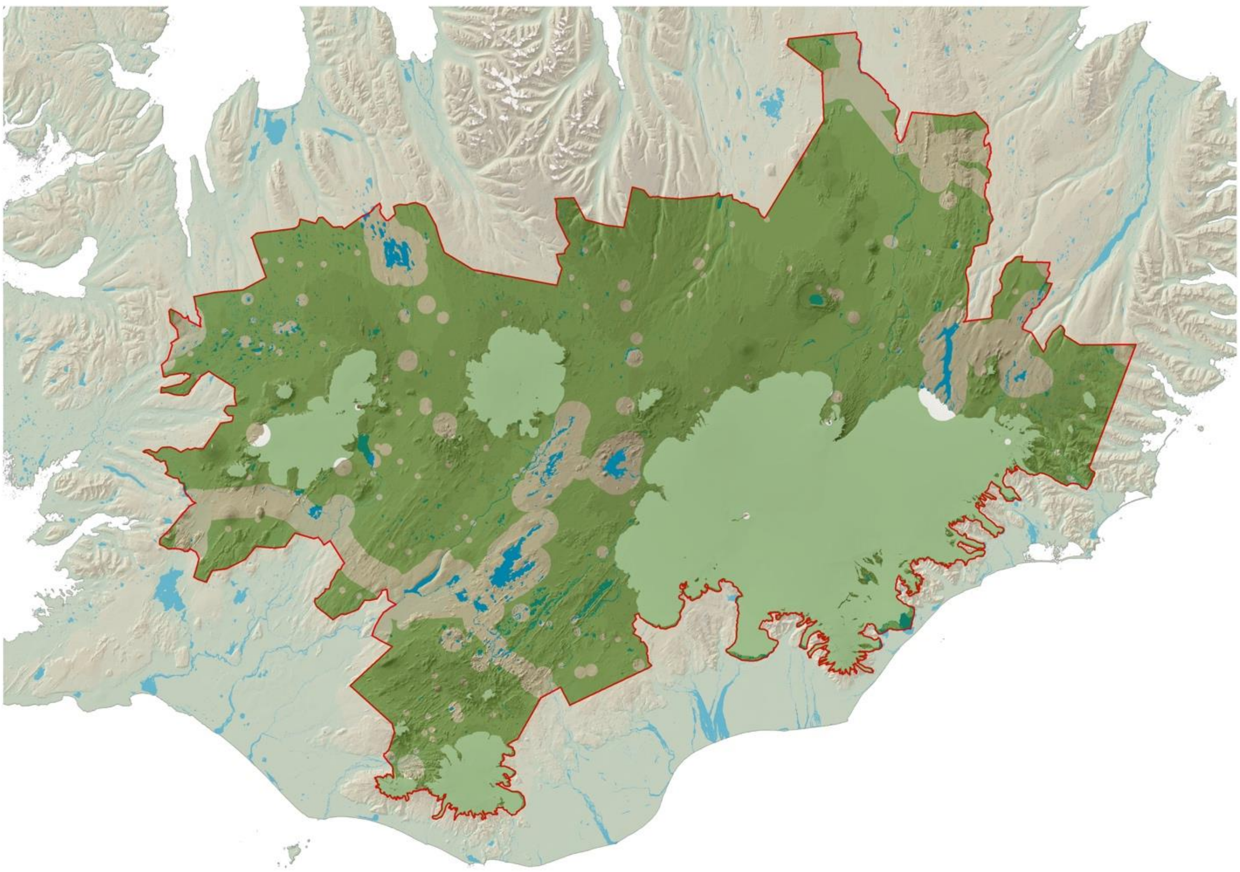
Kortlagning víðerna á miðhálendinu:

Framhaldsverkefni um þróun aðferðafræði



David C. Ostman og Þorvarður Árnason

Háskóli Íslands – Rannsóknasetur á Hornafirði

HÁSKÓLI ÍSLANDS

Rammaáætlun

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HÁSKÓLI ÍSLANDS

Rannsóknasetur á Hornafirði

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Titill: Kortlagning víðerna á miðhálendinu: Framhaldsverkefni um þróun aðferðafræði

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Inngangur

Í skýrslu þessari verður gerð grein fyrir niðurstöðum framhaldsverkefnis um þróun nýrrar aðferðafræði við kortlagningu óbyggðra víðerna á miðhálendi Íslands. Upphaflega verkefnið var unnið á árunum 2016-2017 og lauk með útgáfu skýrslu þar sem lagðar voru fram tillögur um ýmsar breytingar sem gera mætti á aðferðafræði kortlagningar óbyggðra víðerna.[1] Jafnframt voru unnin fjölmörg kort á grundvelli þessara tillagna, bæði þá um skerðingaráhrif ýmissa flokka eða tegunda mannvirkja, svo og um skerðingaráhrif mannvirkja í heild sinni, miðað við forsendur verkefnisins.

Um það bil ári eftir að ofangreind skýrsla kom út lauk Skipulagsstofnun við verkefni um skráningu mannvirkja og þjónustu á miðhálendinu.[2] Verkefninu er lýst á eftirfarandi hátt í skýrslu Skipulagsstofnunar (s. 5):

> **Tilgangur verkefnisins er að fá heildstæða yfirsýn yfir núverandi húsakost og þjónustuframboð á miðhálendinu. Slík yfirsýn er nauðsynleg forsenda frekari stefnumótunar um skipulagsmál á miðhálendinu, svo sem greiningar víðerna, mats á þörf fyrir uppbyggingu ferðaþjónustumannvirkja og nánari stefnu um vegakerfi miðhálendisins. Auk þess er upplýsingum úr verkefninu ætlað að nýtast við gerð aðalskipulags sveitarfélaga og skapa grundvöll fyrir bættri skráningu mannvirkja á miðhálendinu.**

Við vinnslu þessa verkefnis Skipulagsstofnunar komu í ljós allmörg mannvirki innan hálendismarkanna sem ekki höfðu áður formlega verið skráð. Af þeim sökum hafði ekki verið mögulegt að skoða áhrif umræddra mannvirkja í upphaflega kortlagningarverkefninu 2016-2017 og því töldu höfundar þessarar skýrslu mikilvægt að ‚uppfæra' greiningarinnar sem áður höfðu verið gerðar m.t.t. þessara nýju gagna. Tillaga um framhaldsverkefni var lögð fyrir faghóp 1 í fjórða áfanga Rammaáætlunar og síðar fyrir verkefnisstjórn Rammaáæltunar sem samþykkti að leggja fjármuni til vinnslu þess. Vinnan fór að mestu fram árið 2019, en kortin voru uppfærð í ársbyrjun 2020, á grundvelli gagna sem þá höfðu nýlega birst um mannvirki á hálendinu önnur en byggingar.

David C. Ostman, umhverfis- og auðlindafræðingur, bar hitann og þungann af LUK-vinnu og greiningum vegna þessa framhaldsverkefnis. Meginefni þessara skýrslu er greinargerð hans (skrifuð á ensku) um niðurstöður verkefnisins, en hér að neðan verður gefin stutt samantekt um helstu niðurstöður þess. Nánari upplýsingar um aðferðaferði kortlagningarinnar sem beitt var má finna í áðurnefndri skýrslu frá 2017.

[1] Þorvarður Árnason, David C. Ostman og Adam Hoffritz (2017). *Kortlagning víðerna á miðhálendi Íslands: Tillögur að nýrri aðferðafræði*. Höfn: Rannsóknasetur Háskóla Íslands á Hornafirði. http://www.ramma.is/frettasafn/skyrsla-um-kortlagningu-viderna-litur-dagsins-ljos

[2] Skipulagsstofnun (2018). *Mannvirki á miðhálendinu. Framfylgdarverkefni Landsskipulagsstefnu 2015–2026.* Reykjavík: Skipulagsstofnun. https://www.landsskipulag.is/um-landsskipulagsstefnu/frettir/kynning-a-skyrslunni-mannvirki-a-midhalendinu-1-2

Í upphaflega kortlagningarverkefninu 2016-2017 voru áhrif mannvirkja á óbyggð víðerni metin út frá gagnagrunni sem innihélt upplýsingar um 471 mannvirki (þ.e. einstakar byggingar) af ólíkum toga, auk upplýsinga um vegi, miðlunarlón og raflínur innan marka miðhálendisins. Skráningarverkefni Skipulagsstofnunar leiddi í ljós 152 byggingar til viðbótar innan marka miðhálendisins, þannig að uppfærður gagnagrunnur framhaldsverkefnisins samanstóð af upplýsingum um 623 mannvirki. Miðað við upphaflegan fjölda, þá samsvararaði þessi viðbót um það bil þriðjungs aukningu á manvirkjum sem unnt var að taka til skoðunar.

Flokkar mannvirkja	2017	2020
Fjallaskálar	282	388
Hesthús	50	50
Salerni og hreinlætisaðstaða	38	59
Virkjanamannvirki	31	31
Geymslur	16	21
Fjarskipta innviðir	13	13
Starfsmannahús	10	14
Þjónustumiðstöðvar	7	7
Hótel og gestahús	7	16
Söluskálar	5	5
Óþekkt	5	6
Býli	5	11
Samgöngumannvirki	2	2

Langflest þeirra áður óskráðu mannvirkja (ríflega 100 talsins) sem skráningarverkefni Skipulagsstofnunar leiddi í ljós féllu í mannvirkjaflokinn „fjallaskálar“ (sjá nánar samanburðartöflu hér að ofan). Hér var því oftast um tiltölulega lítil og lágreist mannvirki að ræða. Mörg þeirra voru jafnframt í grennd við byggingar sem áður voru þekktar. Mannvirki af þessum toga hljóta alla jafnan fremur lága áhrifaeinkunn miðað við þær forsendur sem liggja aðferðafræði kortlagningarinnar til grundvallar (sjá nánar bls. 13-17 í skýrslunni frá 2017). Nýja greiningin, á grunni uppfærðra gagna, leiddi enn fremur í ljós nokkur tilvik þar sem skerðingaráhrif einstakra mannvirkja eða mannvirkjaklasa reyndust minni en áður hafði verið talið; þetta skýrast af því að skráning Skipulagsstofnunar (2018) var nákvæmari en þær skráningar, í ólíka og mis-ítarlega gagnagrunna, sem áður höfðu verið gerðar. Á heildina litið reiknuðust skerðingaráhrif bygginga vera um 13 km^2 minni en talið var árið 2017 (sjá töflu hér að neðan).

Gerð mannvirkis	2017 Skerðing (km^2)	2020 Skerðing (km^2)	2020 Hlutfall
Byggingar	2.314	2.301	24,8%
Vegir	1.939	2.114	23,9%
Miðlunarlón	2.886	2.935	31,7%
Raflínur	1.918	1.918	20,7%
Samtals	**9057**	**9268**	**100,1%**

Mestu skerðingaráhrif til viðbótar þeim sem áður höfðu verið greind stöfuðu af lengingu uppbyggðra vega innan hálendisins, svo og vegna stærri mannvirkjaklasa (sjá Figure 7a/b hér á eftir). Þá reiknuðust skerðingaráhrif miðlunarlóna nokkuð meiri en árið 2017. Skerðingaráhrif mannvirkja annarra en bygginga voru metin út frá nýjustu upplýsingum um (a) vegakerfi landsins og (b) vatnafar (þar sem miðlunarlón eru tilgreind) frá Landmælingum Íslands.[3] Þessar þekjur voru uppfærðar á vef Landmælinga Íslands 24. desember 2019 og voru kort þessa verkefnis endurunnin með tilliti til þeirra í ársbyrjun 2020. Upplýsingar um legu raflína á miðhálendinu voru fengnar af kortavef Landsnets.[4] Ein breyting var gerð á aðferðafræði verkefnisins sem kynnt var í skýrslunni 2017; hún felst í því að í núverandi útreikningum og kortum er *ekki* gert ráð fyrir skerðingaráhrifum af öðrum vegum en þeim sem hafa bundið slitlag. Þrátt fyrir þessa breytingu vega skerðingaráhrif uppbyggðra vega áfram talsvert þungt í samanburði við aðrar gerðir mannvirkja (sbr. töfluna hér að ofan).

Eftir að tekið hefur verið tillit þess að áhrifasvæði mannvirkja geta ‚fallið saman' í hluta eða heild (sjá nánar Figure 8 hér á eftir), þá reiknast heildaráhrif allra mannvirkja sem tekin voru til skoðunar í þessu verkefni ná yfir 6.675 km^2 en sú tala samsvarar um 16,7% af heildarflatarmáli miðhálendisins (39.874 km^2). Áhrif allra mannvirkja sem skoðuð voru árið 2017 (að frátöldum óuppbyggðum hlutum stofnvega) námu samtals 6.488 km^2 þannig að reiknuð skerðingaráhrifin hafa á heildina litið aukist nokkuð frá því sem áður var talið. Þótt munurinn á útkomu milli ára hafi ekki reynst mikill þegar upp var staðið ber að hafa í huga að afurðir þessa nýja verkefnis byggja á mun heildstæðari og betri gögnum en áður voru fyrir hendi um einstakar byggingar og einnig á uppfærðum gögnum um tvo af þremur öðrum meginflokkum mannvirkja (þ.e. vegi og miðlunarlón).

Höfundar þakka sérfræðingum í faghópi 1 og starfsfólki Skipulagsstofnunar fyrir gott samstarf. Verkefnisstjórn Rammaáætlunar færum við einnig þakkir fyrir fjárhagslegan stuðning við verkefnið.

[3] https://www.lmi.is/en/stafraen-gogn/
[4] https://www.map.is/landsnet/

Mapping Wilderness in the Icelandic Central Highland

David C. Ostman

Introduction

The purpose of this project is to outline a novel approach to mapping wilderness in Iceland's Central Highland. This mapping methodology described below was first developed and applied in the early Spring of 2017, in consultation with Iceland's National Planning Agency (Skipulagsstofnun) and the Environment Agency (Umhverfisstofnun), for the purpose of updating the wilderness map that had been developed by Icelandic authorities at that time. The same methodology from 2017 was subsequently applied in the Spring of 2019 and again, most recently, in January 2020, to create an updated version of the map based on the newest and most accurate, available data.

The goal of the project was to create a systematic, transparent, and dynamic method to map wilderness, based specifically on the impacts of manmade structures (predominantly roads, reservoirs, power lines, and buildings). The mapping process involved the following steps:

I. Identify all manmade structures in the Central Highland and consolidate pre-existing structure databases into one comprehensive database
II. Classify building structures into general categories based on usage
III. Determine measurable criteria or characteristics of manmade structures that impact wilderness (e.g. size, visibility, usage type, accessibility, clustering)
IV. Develop scoring system comprised of impact ranges, criteria metrics, and corresponding distance buffers assigned to each structure
V. Upload database into GIS to provide visual representation of the structure buffers and resulting wilderness areas

This report will discuss the procedure of creating the wilderness map, which is meant to act as a framework for evaluating the impact on wilderness caused by current and future infrastructure. The overall objective is for this work to enhance credibility regarding wilderness conceptualization and mapping in general and strengthen its usability for Icelandic nature conservation, strategic planning, and land use decision-making.

Identify manmade structures and consolidate databases

The first objective in this mapping process was to determine and consolidate all of the known manmade structures that exist in the Central Highland. For the purpose of this project, the structures that were identified consisted predominantly of *building* structures and excluded other, less intrusive, manmade structures such as bridges, signs, and fences. Cultural remains, archaeological ruins, and other historically/culturally significant artifacts would ideally have been included, but due to a lack of data at the time, this category of structures was left out of the database and mapping process.

There were four main databases of manmade structures (all in the form of excel spreadsheets) that were used in the original 2017 map:

I. The National Register of Iceland Database (Þjóðskrá Íslands)
II. The National Land Survey of Iceland Database (Landmælingar Íslands)
III. Vatnajökull National Park Database (Vatnajökulsþjóðgarður)
IV. Miscellaneous Database consisting of registered structures from municipalities, local plans, The National Register, Mountain Huts of Iceland (Fjallaskálar á Íslandi), and The Travel Association of Iceland (Ferðafélag Íslands)

The 2019 map included newly-identified manmade structures from an additional database provided by Skipulagsstofnun:

I. Tourism Structures (Ferðaþjónustumannvirki)

There were no new structures added to the database for the 2020 mapping update.

Most of the databases contained similar structures from the other databases as well as new structures not already identified, so each structure in each database had to be assessed one at a time. This was also important since those structures that appeared in more than one database did not always contain the same information. Therefore, it was necessary to cross-reference each database manually, matching up similar structures with each other and adding in any new information.

The structure information from the databases above was copied into a new database in the form of an Excel spreadsheet with each database grouped into color-coded columns to distinguish one database's information from another. The data of any similar structures were matched up in the same row (see Figure 1 for a snapshot of the new database format). During the initial 2017 mapping process, a total of 471 manmade structures were identified and logged in the new database. After the 2019 mapping process, an additional 152 structures were identified for a total of 623 structures.

The new database preserved the *original* database information (i.e. any information already within the existing databases) as well as identified *new* information that was deemed important for the wilderness mapping assessment process. This new information included the following:

I. New reference number
II. Structure category
III. Structure cluster
IV. GPS (x,y) coordinates (converted to meters format used for compatible GIS upload)
V. Raw data needed for scoring the criteria (discussed below)
VI. Scores for each criteria and resulting buffer radii (discussed below)

Combined Database									
								Surface Area (m2)	
Number	Structure Category	New Structure Category (Adam/Ester)	New Structure Category (Icelandic)	Structure Name	Structure Cluster	X	Y	Surface Area	Impact Score
228	Shed	Storage	Geymsla	Hellishólmi		403002.391	487818.996	33.5	0
272	Mountain Hut	Mountain Hut	Fjallaskálar	Hvítárnes	Hvítárnes	463747	457626	40.7	0
435	Mountain Hut	Mountain Hut	Fjallaskálar	Bergland		531085.7414	521387.0509	56	1
271	Storage	Storage	Geymsla	Hvítárnes	Hvítárnes	463816.582	457501.3	21	0
264	Mountain Hut	Mountain Hut	Fjallaskálar	Hveravellir	Hveravellir	473781.671	485253.581	45.5	0
350	Sheep Herding Hut	Mountain Hut	Fjallaskálar	Skælingar		523411	386454	32.3	0
221	Mountain Hut	Mountain Hut	Fjallaskálar	Hagavatnsskáli		440148	440687	19.3	0
454	Mountain Hut	Mountain Hut	Fjallaskálar	Skútagil		407973.7163	495669.6776	48	0
127	Mountain Hut	Mountain Hut	Fjallaskálar	Álftavötn		515186	377173	41.6	0
45	Unknown	Mountain Hut	Fjallaskálar	Möðrudalur/lóð 3	Möðrudalur	644933	545281	133	4
212	Stable	Stable	Hesthús	Gilsbakkasel		405686.798	480101.369	58.8	1
312	Mountain Hut	Mountain Hut	Fjallaskálar	Laugafell	Laugafell	531472	503324	31.5	0
36	Church	Farm	Býli	Möðrudalskirkja	Möðrudalur	644931	545317	30.4	0
137	Mountain Hut	Mountain Hut	Fjallaskálar	Ásgarður	Kerlingarfjöll	485669	464798	65.7	1
189	Sheep Herding Hut	Mountain Hut	Fjallaskálar	Bugaskáli/Eyvindarstaðaheiði		479727.1843	524551.8613	86.7	1
224	Stable	Stable	Hesthús	Hallarmúli Afréttur		452310	410931	44.3	0
347	Stable	Stable	Hesthús	Skjaldborg	Skjaldborg	415247.564	430803.236	54	1
418	Mountain Hut	Mountain Hut	Fjallaskálar	Þjófadalir		466330	479551	16.7	0

Þjóðskrá											
MATSNÚMER (Assessment #)	LANDEIGN_NR (Landowner #)	MHLNR	HÆÐ (Height)	EINING	NOTK	TEXTI	FLATARMÁL (Area)	MÆLIEINING (Unit)	BYGGINGARSTIG (Construction Phase)	FJÖLDI_HÆÐA	BYGGINGARÁR
2257397	156923	17	1	1	514	Smíðastofa	126	m²	4	1	
2271080	156923	18			425	Fjárhús með áburðark	336.7	m2	7	1	
2172750	156923	11	1	1	408	Véla/verkfærageymsla	59.5	m2	7	0	
2172751	156923	12	1	1	408	Vélageymsla	32.5	m2	7	1	
2172754	156924	1	1	1	563	Kirkja	30.4	m2	7	1	
2205428	167308	1	1	1	567	Skáli	56.1	m2	7	1	
2202907	166705	1	1	1	572	Fjallaskáli og hesth	94.8	m2	7	1	
2196087	164853	1	1	1	571	Sæluhús	66.3	m²	7	1	

Fig. 1. New database layout showing a sample of some of the new information added to the structures (top). An example of one of the original databases (Þjóðskrá) and some of the information preserved (bottom).

As mentioned above, each structure was identified manually, point-by-point. The goal was to collect as much information as possible to identify the structures, but at least enough information needed for the purpose of this project to evaluate their impact on wilderness. Many of the structures listed in the original databases already contained enough information to identify them, such as geographic location (GPS coordinates) and the structure name, but in many cases, limited information was given, so further investigative methods had to be used in the identification process. These methods included photo and web searches, aerial and satellite image searches (map.is, Loftmyndir, SPOT 5 images, GoogleEarth), and outreach to organizations and municipalities.

Classifying structures into categories

Once all of the original databases were cross-referenced and added to the new database, then each structure was classified into 1 of 13 categories. These categories were decided upon in consultation with Skipulagsstofnun and predominantly based on structure usage. See Table 1 for a full list of the categories. Cultural remains and artifacts would have been an additional structure category, but as noted in the previous section, the data for these structures were not accessible at the time of this mapping analysis.

Table 1. Breakdown of the 13 structure categories assigned to each structure

Manmade Structure Categories
Samgöngumannvirki / Transportation Infrastructure
Söluskálar / Food Service
Óþekkt / Unknown
Þjónustumiðstöðvar / Service Center
Býli / Farm
Fjarskipta innviðir / Telecommunication
Starfsmannahús / Staff Office
Hótel og gestahús / Hotel or Guesthouse
Geymslur / Storage
Virkjanamannvirki / Energy Structure
Hesthús / Stable
Salerni og hreinlætisaðstaða / Bathroom Facilities
Fjallaskálar / Mountain Hut

Initially, other more specific categories were assigned to each structure, but then these were consolidated into the 13 more general categories. Both sets of categories can be seen in Table 2.

Table 2. Detailed structure categories (left column) grouped into the finalized 13 categories (right column)

Manmade Structure Category	Manmade Structure Category (consolidated)
Airport Infrastructure	Transportation Infrastructure (Samgöngumannvirki)
Parking Lot	
Sanitary Facilities	Bathroom Facilities (Salerni og hreinlætisaðstaða)
Bathroom Facilities	
Guesthouse	Hotel or guesthouse (Hótel og gestahús)
Hotel	
Hydropower Plant Structure	Energy Structure (Virkjanamannvirki)
Staff House	Staff Office (Starfsmannahús)
Park Ranger Office	
Service Center	Service Center (Þjónustumiðstöðvar)
Shared Recreational Facility	
Restaurant	Food Services (Söluskálar)
Cooking facilities	
Farm	Farm (Býli)
Church	
Turf House	Storage (Geymslur)
Storage	
Shed	
Stable	Stable (Hesthús)
Research Station	Mountain Hut (Fjallaskálar)
Sheep Herding Hut	
Emergency Hut	
Mountain Hut/Fishing Hut	
Mountain Hut and Stable	
Power Station (small scale)	
Private Residence	
Summer Cottage	
Radio Tower	Telecommunication (Fjarskipta innviðir)
Telecommunication Station	
Telecommunication Tower	
Unknown	Unknown (Óþekkt)

Unsurprisingly, the largest structure category in the Central Highland was "mountain huts". The total percentage distribution of structure types in the consolidated database for both the 2017 and 2019/2020 analyses is represented in figure 2.

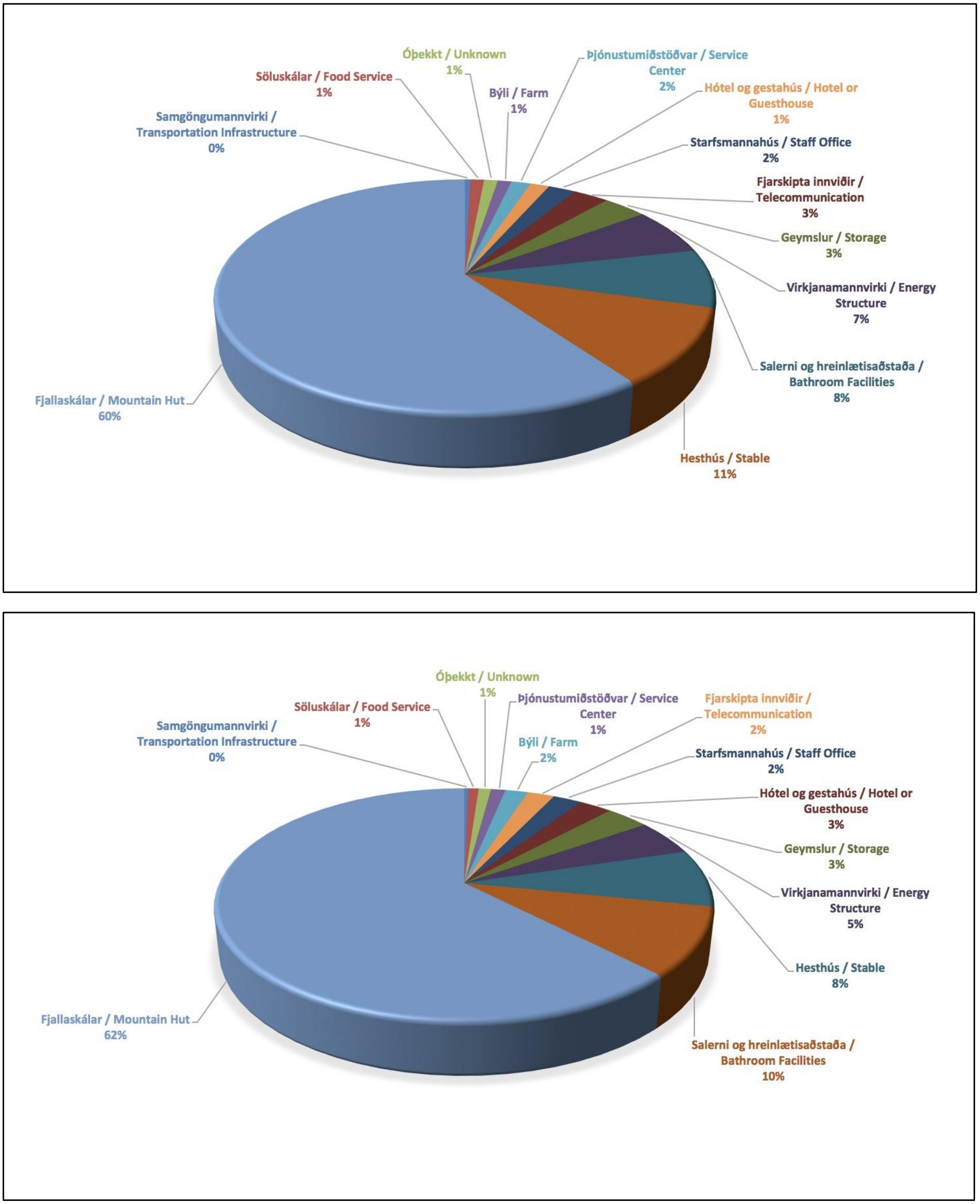

Fig. 2. Percentage distribution of structure categories in the consolidated database for both the 2017 (top) and 2019/2020 (bottom) mapping analyses

Figure 3 shows the geographic distribution of all 623 structures in the 2019/2020 analysis.

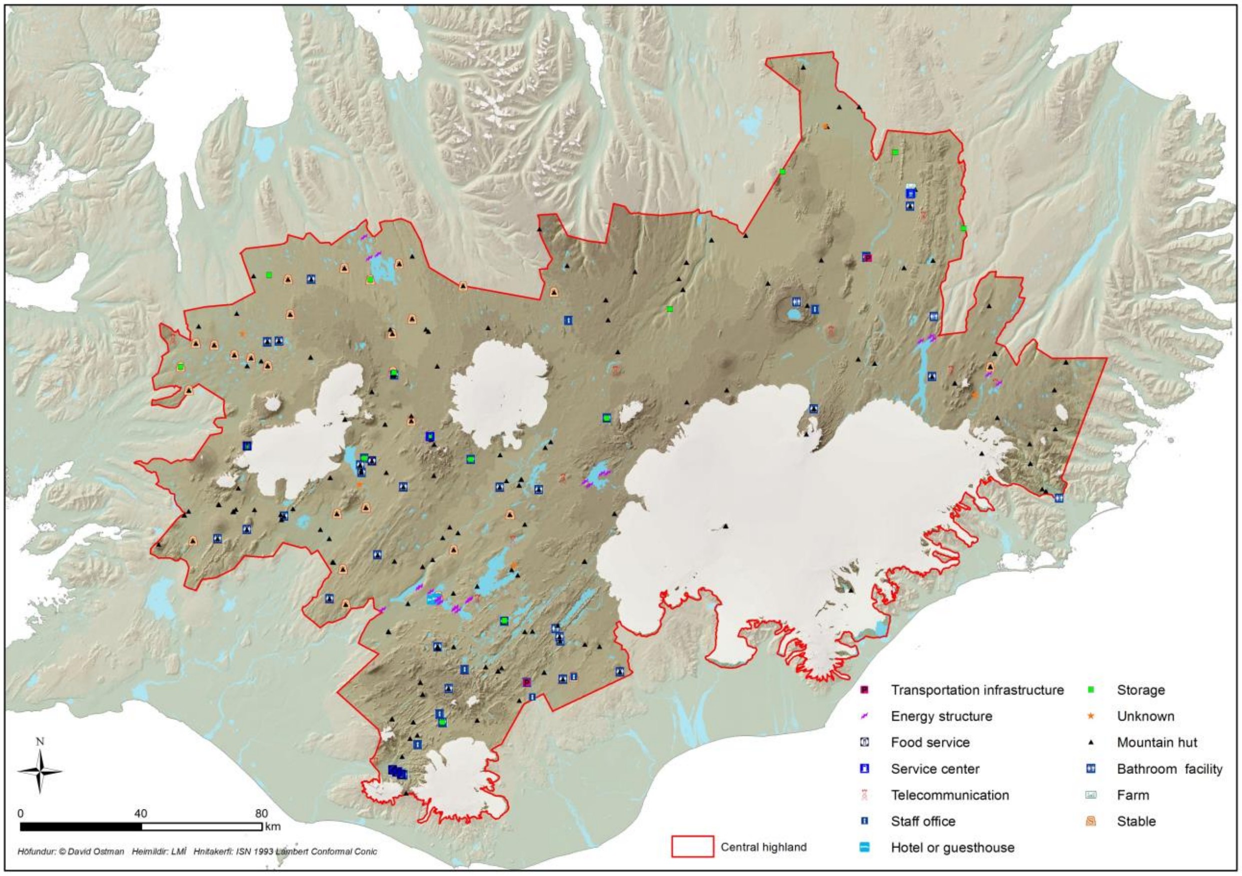

Fig. 3. Geographic distribution of all 623 structures broken down by structure category as of the 2019/2020 analyses

Classifying each structure into one of these categories served a general purpose of grasping the spectrum of structure types within the Central Highland. But beyond this, the structure category (usage) became one of the criteria for determining wilderness impact, as will be discussed in more detail below.

Determining criteria that affect wilderness

There are a variety of objective and subjective factors that influence wilderness and one's perception of the wilderness experience. For the purpose of this project, the criteria selected were those that were objective and measurable, specifically those that could be used or calculated within a GIS environment. ESRI's ArcGIS was used for all data analysis and map processing. The same criteria and mapping procedure were applied to the original 2017 map and updated 2019 and 2020 maps. Ultimately, 6 criteria were selected to yield a score for each structure and determine its impact on wilderness:

I. Structure Usage
II. Surface Area
III. Clustering
IV. Connectivity (road type)
V. Connectivity (distance to closest road)
VI. Visibility

Structure Usage: This criteria refers to the main purpose served by the structure. The original databases from which the structures came often contained usage information, but for those that were unclear, the usage was determined manually (web searches based on the structure name, consultation with Skipulagsstofnun).

Surface Area: The surface area of many of the structures was already provided in the original databases. For the remaining structures without this data, map-measuring tools (map.is and ArcMap) with satellite/aerial imagery were used to measure the surface area.

Clustering: This criteria was defined as the number of structures within a 1km radius of each other. The Point Statistics tool in ArcMap was used for this calculation. An extra field in the attribute table of the structures shapefile had to be added, and all rows in that field had to contain a value of '1' since the Point Statistics tool would apply the 'sum' statistic type to that field and add the number of points within the 1km radius designation. The output will be a raster layer containing pixel values that represent the number of structures within each point's 1km radius. The Extract Values to Points tool was then used to connect the pixel value of the point statistics output raster to the point structures layer by adding a new field in that layer's attribute table called RASTERVALU. The number in each row of that field is thus the number of points that are within a 1km radius of that point.

Connectivity: The connectivity of a structure refers to how accessible the structure is based on the distance to the closest road and the type of road. In other words, the criterion has two components- the *distance* from each structure to the closest road and the *type* of that closest road. The road type refers specifically to the level of road quality as defined by the Icelandic Road Authority (Vegagerðin), specifically road types A, B, C, D, F1, F2, F3. The distance to the closest road sub-criterion was measured 'as the bird flies'- a straight line from the structure to the nearest road segment. The Near Tool in ArcMap was used to determine this calculation. The tool's search radius needed to be large enough so as to not overlook any structures that were quite far from the nearest road, so a radius of 50 km was used. The output produced two new fields in the attribute table of the input feature (in this case, the structure layer): A field called Near FID (the number of the road to which the structure is closest) and a field called Near DIST (the distance from the structure to the road). The Add Join tool was then used to align the road number (FID) in both the structure layer and the road layer attribute tables and thus determine the respective road type (A, B, C, etc...).

Visibility: A modelbuilder in ArcGIS was used to calculate the visibility for each structure (Figure 4). The modelbuilder included the Visibility Analysis tool and Iterate Feature Selection tool. In the Visibility tool, the digital elevation model (DEM) and structure shapefile layer were attached as inputs, and a generic observer offset (height) of 3 meters and maximum outer radius of 50km were set as the visibility criteria. Depending on the number of points inputed to the tool, the visibility can take some time to process. In this case of the 623 points, the processing time was about 3.5 days.

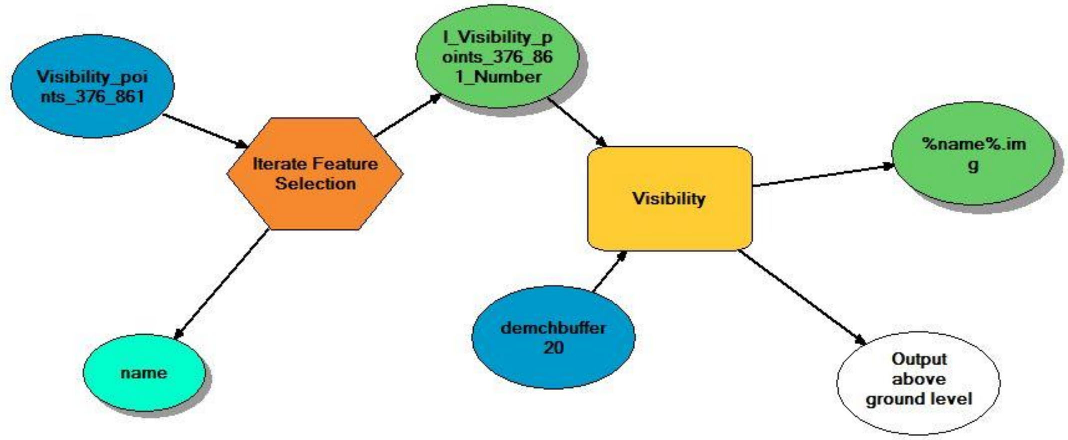

Fig. 4. Modelbuilder created in ArcGIS to calculate the building structure visibility for all 623 points

Other potential criteria were discussed such as structure age, height, temporary vs. permanence, and cultural significance, but due to either lack of data or an insufficient, measurable definition of the criteria, they were not used in this project.

Developing a scoring system

A scoring methodology was created in order to give one score for each criteria and then one total score (i.e. the accumulated individual scores) for each structure based on all six criteria. Each criterion was assigned a metric, impact range, and an impact score based on an existing scoring scheme. This scoring scheme was adopted from Iceland's Master Plan for Nature Protection and Energy Utilization (Rammaáætlun) and used a non-linear scoring system of 0, 1, 4, 8, 13, 20. Table 3 shows the final metrics, impact ranges, and scores used for each criterion.

Table 3. Shows the six criteria used to assess point structures and how each structure was given its individual score

Impact Criteria	Metric	Impact Range	Impact Score (0,1,4,8,13,20)
Structure Usage	Category	Transportation Infrastructure	4
		Bathroom Facilities	1
		Hotel or guesthouse	8
		Energy Structure	20
		Staff Office	1
		Service Center	13
		Food Services	8
		Farm	4
		Storage	1
		Stable	1
		Mountain Hut	1
		Telecommunication	8
		Unknown	1
Surface Area	m2	0 - 49	0
		50 - 99	1
		100 - 149	4
		150 - 199	8
		200 - 249	13
		250 +	20
Clustering	# of points within 1km radius	0 - 1	0
		2 - 3	1
		4 - 5	4
		6 - 7	8
		8 - 9	13
		10 +	20
Connectivity	Road Type	F3	0
		F2	1
		F1	4
		D	8
		C	13
		A-B	20
	Distance to closest road (km)	10 +	0
		8 - 9	1
		6 - 7	4
		4 - 5	8
		2 - 3	13
		0 - 1	20
Visibility	Cell Count	0 - 299.999	0
		300.000 - 599.999	1
		600.000 - 899.999	4
		900.000 - 1.199.999	8
		1.200.000 - 1.499.999	13
		1.500.000 +	20

For each structure, the individual scores for each of the six criteria were added together to get a total impact score (out of 120). Each total impact score then fell within a total score range that yielded a buffer equivalent (out of 7), shown in Table 4. The buffer would be the actual radius (in km) applied to each structure to reduce wilderness on the final GIS map.

Table 4. Summated impact score ranges and buffer equivalents implemented for each structure on the final map

Total Impact Score	Buffer Equivalent (0-7 km)
0 - 15	0
16 - 30	1
31 - 45	2
46 - 60	3
61 - 75	4
76 - 90	5
91 - 105	6
106 - 120	7

For some outlier structure types (i.e. non-building structures) we either used a simplified method to determine their buffers or gave them a fixed buffer. These structure types included roads, reservoirs, and power lines. Roads used the road type criterion as defined by the National Road Authority (Vegagerðin). There was some uncertainty as to what kind of roads within the Central Highland should be considered to affect wilderness; the majority of the roads there are unpaved and some are more heavily traveled than others. It was agreed that all category C roads that were paved would receive a buffer above '0' (predominantly only category C roads within the Central Highland are paved). The more heavily traveled roads were experimented with having a buffer but were ultimately still given a buffer of '0' in the final wilderness maps (these roads include Sprengisandsleið, Kaldidalur, Kjalvegur, and Fjallabaksleið nyrðri, which are coded as a special road group '8' under 'Vegflokkun' according to Vegagerðin). Power line buffers were based on the voltage (kV), and reservoirs were given a generic buffer. Table 5 shows a breakdown of the metrics, impact ranges, and buffers used for these non-building structures.

Table 5. Criteria used for non-building structure types (roads, reservoirs, and power lines).

Structure Type	Metric	Impact Range	Buffer (0-7 km)
Roads	Quality Type	F3	0
		F2	0
		F1	0
		D	0
		C (Excluding paved roads)	0
		C (Only paved roads) (#10)	5

Structure Type	Metric	Impact Range	Buffer (0-7 km)
Reservoirs	Category	Reservoir	5

Structure Type	Metric	Impact Range	Buffer (0-7 km)
Power Lines	Voltage (kV)	132	3
		220	5

Uploading database to GIS and creating wilderness map

Once the GIS analysis was applied to all building structures for all six criteria, the resulting raw data was added to the structure database. The following information for each building in the database, including the raw data, was included for organizational purposes:

I. Unique reference number
II. Structure category
III. Structure name
IV. Structure cluster (if applicable)
V. GPS coordinates
VI. Surface area (m^2)
VII. Number of points in cluster
VIII. Road type of closest road (A, B, C, D, F1, F2, F3)
IX. Distance to closest road (km)
X. Visibility cell count (# of visible cells)
XI. Individual impact scores for all 6 criteria
XII. Total impact scores
XIII. Equivalent impact buffers (km)

Formulas based on the scoring system were created within the spreadsheet to convert the raw data for each of the six criteria to the individual impact scores, total impact scores, and buffers for each building structure. Once all calculations were finalized and the structure database included all necessary information, the database spreadsheet was uploaded to ArcGIS.

As a GIS layer, the building structures were separated out into their own shapefile layers based on their impact buffers (0-7). The Buffer tool was applied to create a buffer for each respective layer. The most updated non-building structure layers (i.e. roads, reservoirs, and power lines) also needed to be imported to AcrGIS, clipped for the Central Highland boundary, and have their respective buffers applied to them. The most recent iterations of the road and water (reservoir) layers were downloaded from the publicly-accessible database within the National Survey of Iceland (Landmælingar Íslands) website. Since the power line layer is not for public download, their locations were estimated based on the public, interactive map accessible through the National Grid Authority (Landsnet) website.

Once all of the buffers for all of the structures were created, they were merged together using the Merge tool. Then the Clip tool was used to cut the buffers for the Central Highland boundary. Lastly, the Erase Tool was used to create the inverse of the merged buffers, and this remaining polygon resembled the final wilderness area.

Results

Figures 5 and 6 show the final wilderness maps from the original 2017 and most recent 2020 analyses, respectively, after all of the manmade structures were analyzed based on the above methodology.

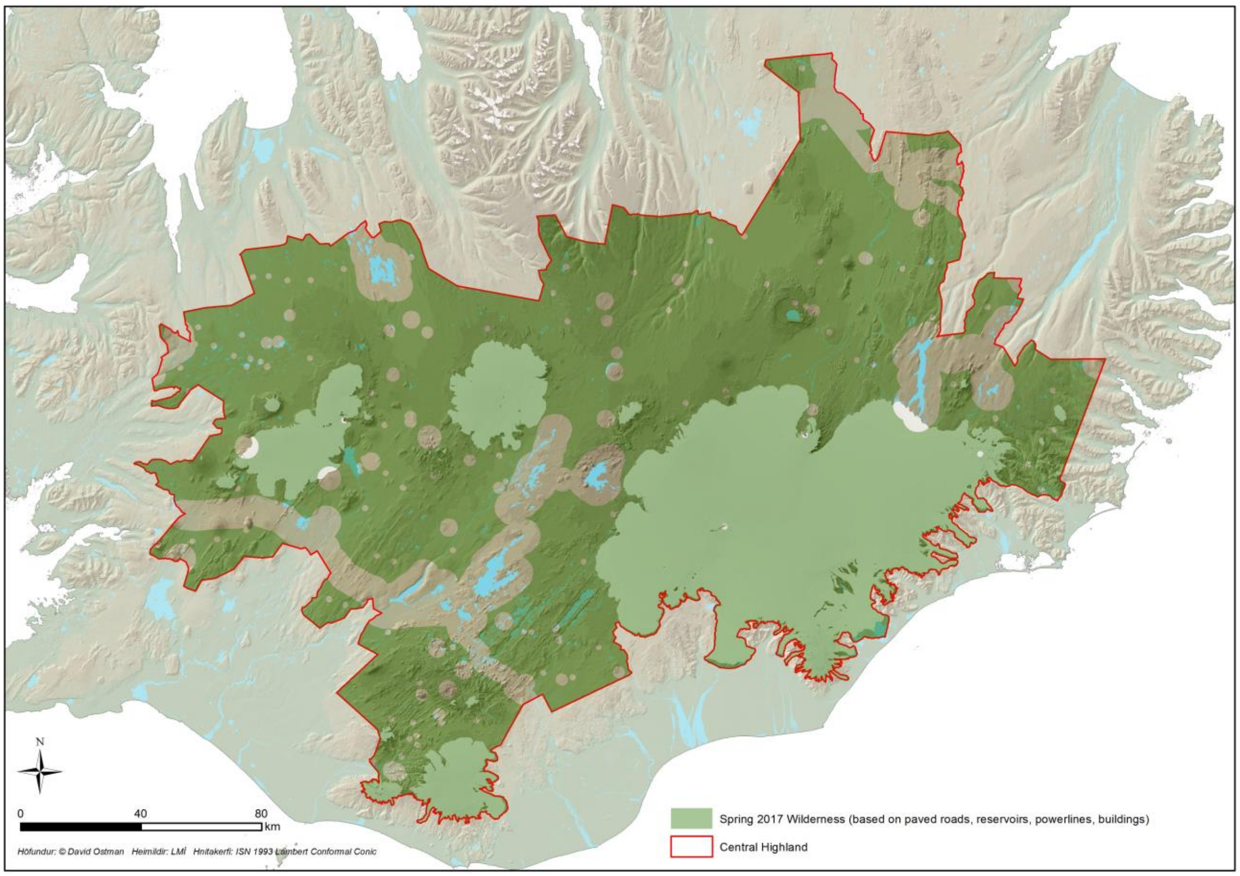

Fig. 5. Final wilderness map for Iceland´s Central Highland (2017 analysis)

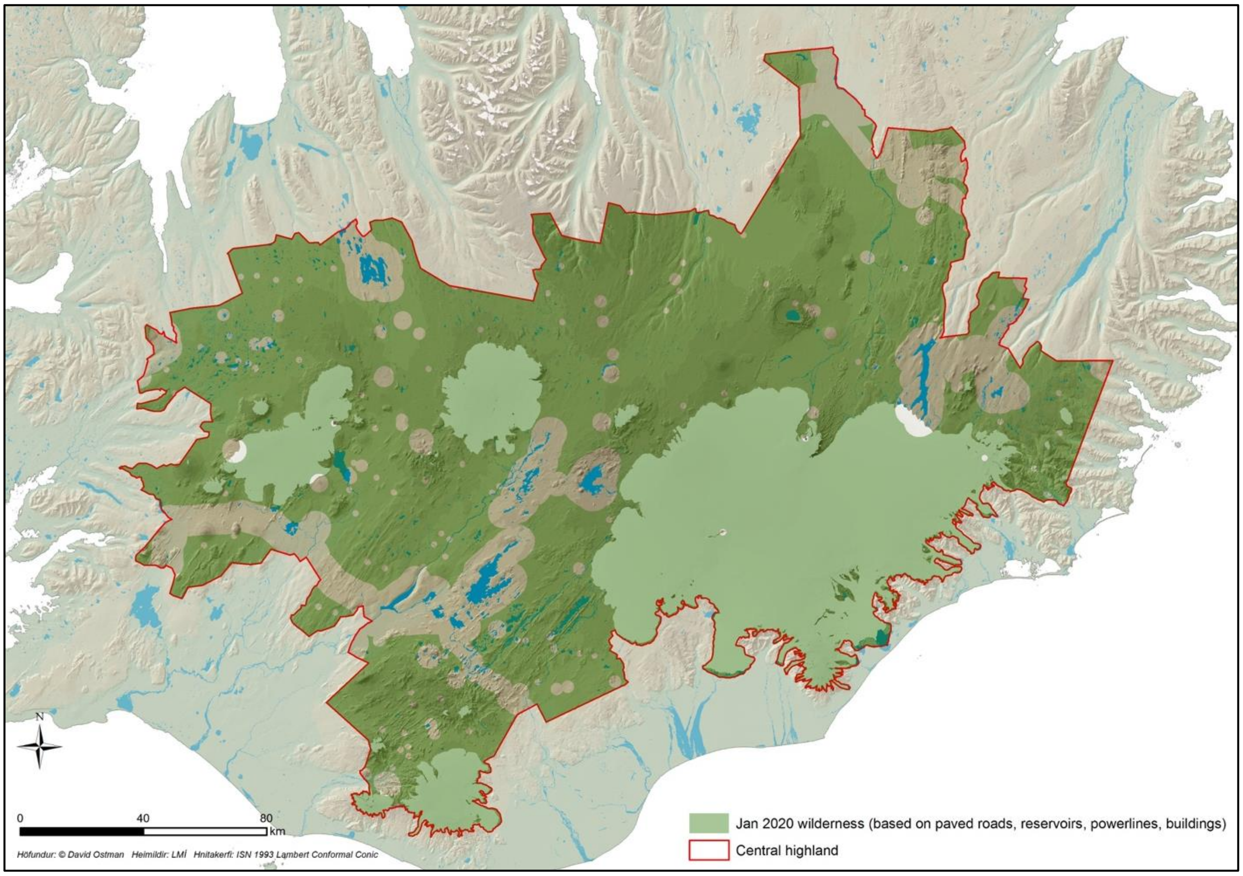

Fig. 6. Final wilderness map for Iceland´s Central Highland (2020 analysis)

Despite the addition of 152 structures between the 2017 and 2019/2020 maps, there was only a relatively small change in the wilderness area (Figures 7a and 7b). The majority of the wilderness loss was predominantly caused by an increase in the amount of paved roads and increased clustering from additional building structures.

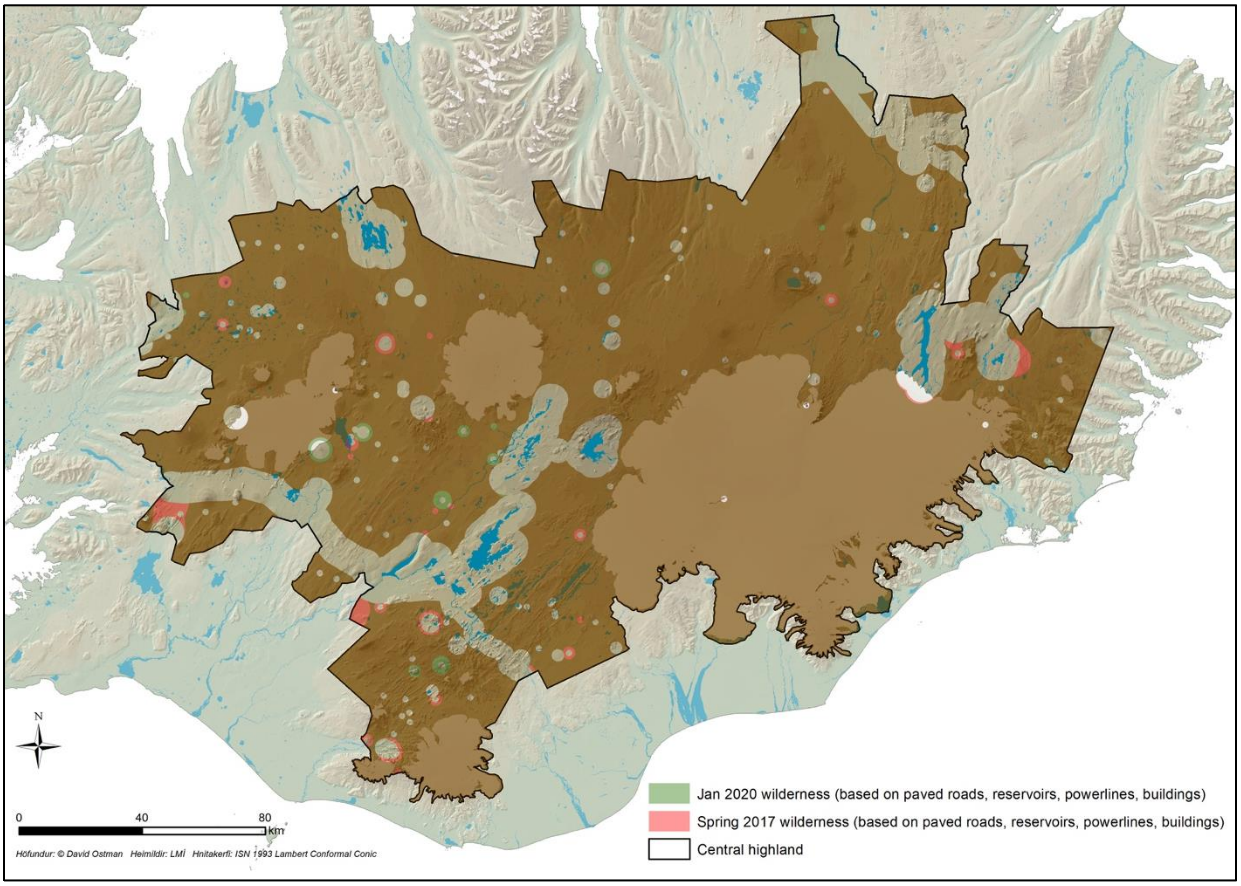

Fig. 7a. Wilderness area comparison from 2017 to 2020 (BROWN represents wilderness that has stayed the same, RED represents wilderness loss in 2020, and GREEN represents wilderness added in 2020).

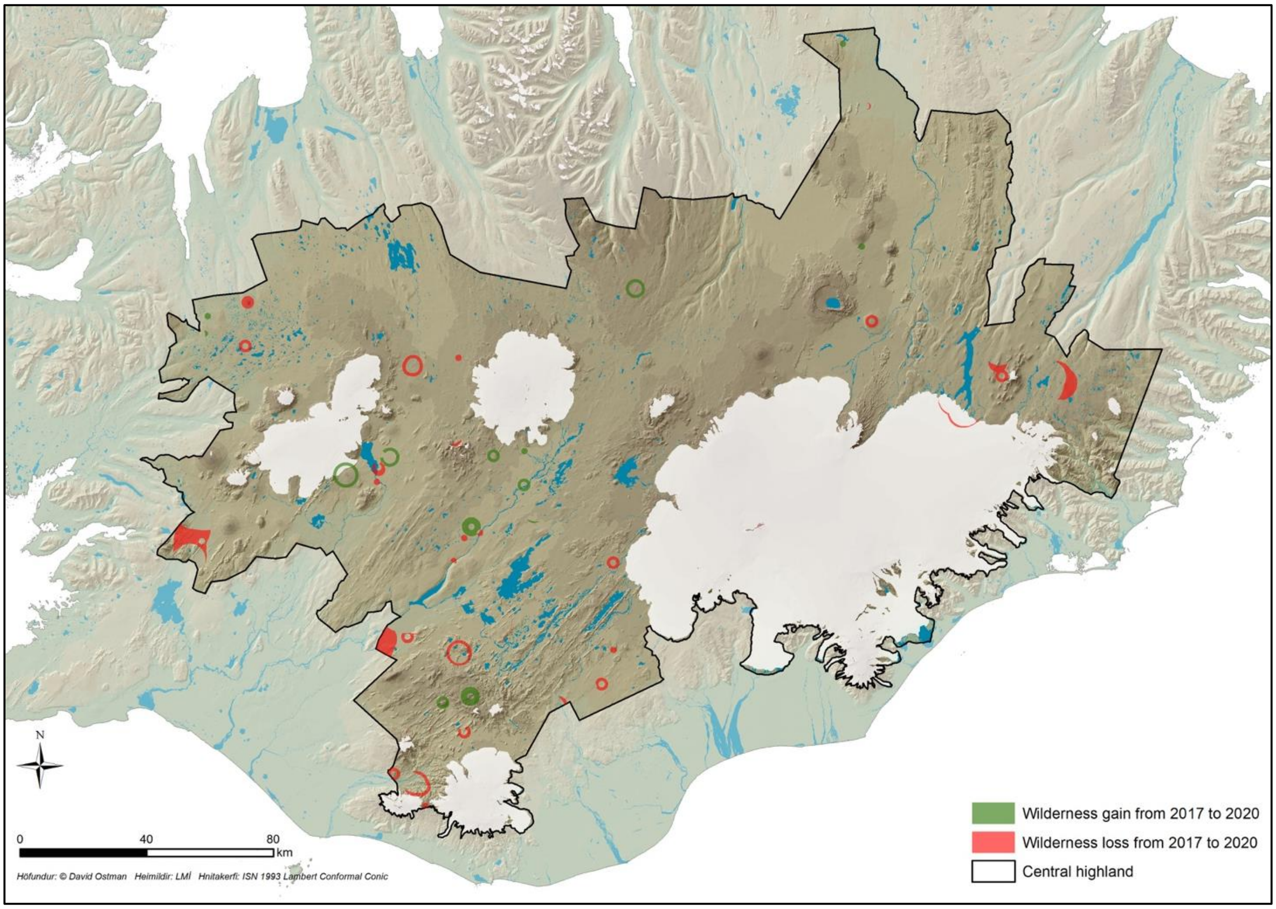

Fig. 7b. Wilderness area comparison from 2017 to 2020 (RED represents wilderness loss in 2020, and GREEN represents wilderness added in 2020).

Figure 8 shows the impact buffers from all structures, specifically what type of structure it is (road, reservoir, power line, or building structure) that causes the impact and the buffer distance.

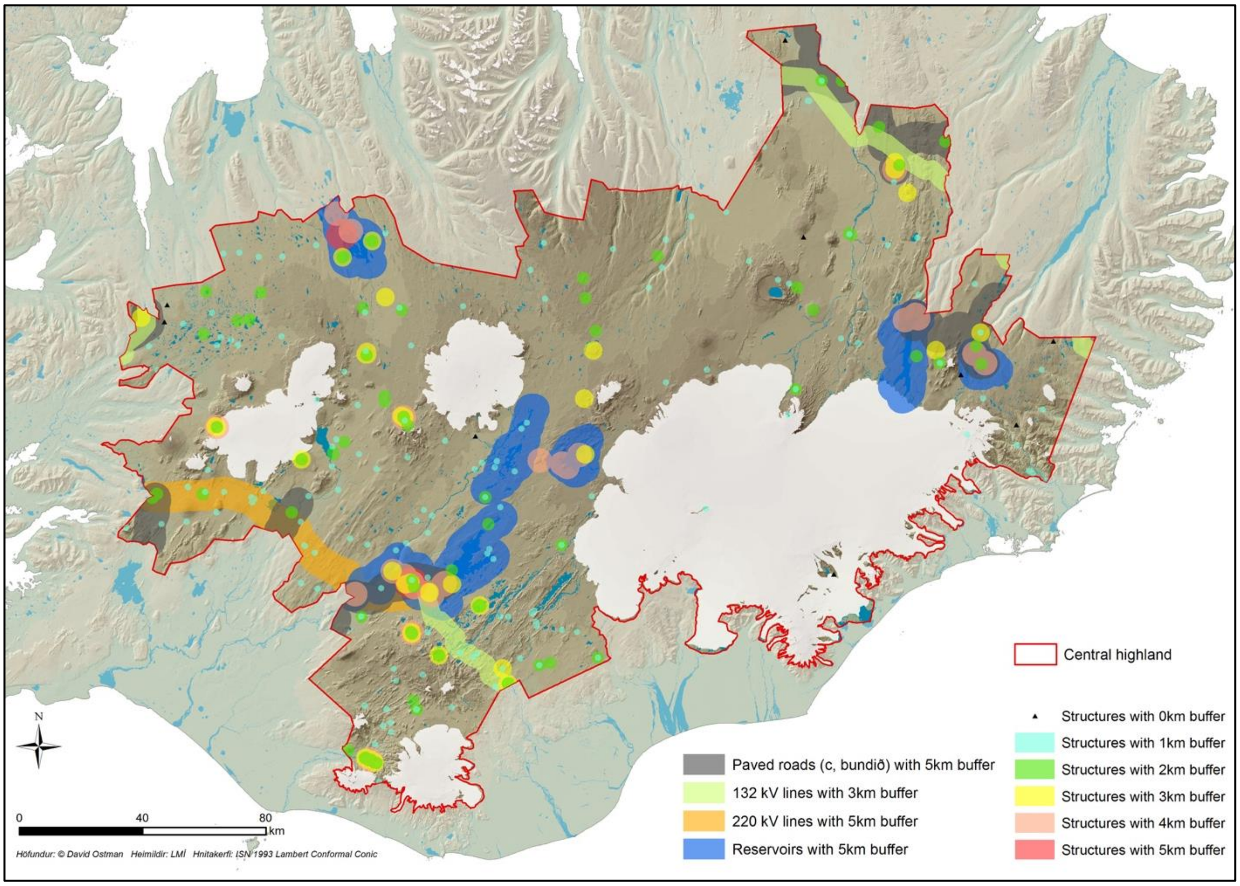

Fig. 8. Impact buffers color-coded based on the general categories of structures (roads, reservoirs, power lines, buildings)

In all mapping analyses (2017, 2019, and 2020), the resulting impact buffers for building structures ranged from 0-5 km (no structure received a ‘6’ or ‘7’ buffer). The distribution of structures based on their category and impact buffer can be seen in Table 6.

Table 6. Comparison between the 2017 (left) and 2019/2020 (right) mapping results showing the distribution of specific structure type based on buffer size

Impact Buffer (0 - 7 km)	Structure Category	Number	Total
0	Mountain Hut	5	8
	Stable	1	
	Unknown	2	
1	Bathroom Facilities	24	223
	Mountain Hut	148	
	Stable	34	
	Staff Office	5	
	Storage	6	
	Telecommunication	3	
	Unknown	3	
2	Bathroom Facilities	10	138
	Energy Structure	1	
	Food Service	2	
	Mountain Hut	98	
	Service Center	3	
	Stable	11	
	Staff Office	4	
	Storage	7	
	Telecommunication	1	
	Transportation Infrastructure	1	
3	Bathroom Facilities	4	58
	Energy Structure	4	
	Food Service	3	
	Hotel or Guesthouse	3	
	Mountain Hut	27	
	Service Center	2	
	Stable	4	
	Staff Office	1	
	Storage	2	
	Telecommunication	7	
	Transportation Infrastructure	1	
4	Energy Structure	22	38
	Farm	4	
	Hotel or Guesthouse	4	
	Mountain Hut	4	
	Service Center	1	
	Storage	1	
	Telecommunication	2	
5	Energy Structure	4	6
	Farm	1	
	Service Center	1	

Impact Buffer (0 - 7 km)	Structure Category	Number	Total
0	Mountain Hut	10	13
	Stable	1	
	Unknown	2	
1	Bathroom Facilities	30	262
	Mountain Hut	186	
	Stable	32	
	Staff Office	2	
	Storage	8	
	Unknown	4	
2	Bathroom Facilities	25	219
	Energy Structure	1	
	Food Service	1	
	Mountain Hut	151	
	Stable	14	
	Staff Office	11	
	Storage	10	
	Telecommunication	5	
	Transportation Infrastructure	1	
3	Bathroom Facilities	4	85
	Energy Structure	4	
	Food Service	4	
	Hotel or Guesthouse	9	
	Mountain Hut	38	
	Service Center	5	
	Stable	3	
	Staff Office	1	
	Storage	3	
	Telecommunication	6	
	Transportation Infrastructure	1	
	Farm	7	
4	Energy Structure	24	39
	Farm	4	
	Hotel or Guesthouse	4	
	Mountain Hut	3	
	Service Center	2	
	Telecommunication	2	
5	Energy Structure	2	5
	Hotel or Guesthouse	3	

Discussion

The methodology outlined in this report applies a fairly simplified analysis of roads, using only road quality and material as criteria to determine its impact. But the road impact debate extends beyond these criteria and could also include factors such as seasonal usage, traffic amount, and visibility. These additional criteria are currently being researched in ongoing mapping experiments with the prospect of their application in future revisions of this methodology.

The use of hard borders versus soft borders to designate wilderness is an ongoing debate. This mapping methodology produces a hard, 'on-off' wilderness boundary and is intended for planning purposes. It would probably not be met with resistance to say, though, that a soft border reflects a more realistic encounter of the perceived wilderness since people experience change transitionally, in relative time and space. For instance, this may happen visually, looking close-up in the immediate area and then peering out farther into the landscape (or vice versa). It may also happen more literally, walking from one place to another. Both cases acknowledge the fact that it would be difficult to draw a hard line and identify it as the precise source of change.

The buffer range given to manmade structures in this methodology (0-7km) appeals to the theory that not all structures should have the same impact on wilderness. But this appeal does not necessarily mean that it will align to national and legal standards. The question must be asked about the ultimate usage(s) of the wilderness map.

The accuracy of the data from the original databases dictates the accuracy of the consolidated database and the final wilderness maps from which they are based. Therefore it is imperative that the original databases contain the most up-to-date data, including newly-built structures, precise geographic coordinates, and surface area measurements. Due to the lack of height information in the original databases, a generic height for all structures had to be used for the visibility analyses, which indeed hindered the accuracy of the resulting cell counts. Work needs to be done to collect and record this information for structures in the Central Highland to tailor future visibility analyses to individual structures. One of several ideal solutions would be the application of LIDAR to create a digital terrain model (DTM) or the use of a higher resolution digital eleveation model (DEM) from which an accurate height and subsequent cell count can be determined.

Conclusion

This report outlines the experimental methodology of Iceland's wilderness map within the Central Highland based on impacts from manmade structures. This undertaking involves many variables that can, and should be, re-evaluated moving forward. Variables such as the types of manmade structures that are (or are not) considered, the scoring scheme, and buffer ranges are dynamic and ideally need to involve consistent deliberation from all stakeholders. This project acknowledges that different types of manmade structures yield different impacts on wilderness and, by applying the above methodology, hopes to enhance the credibility and usefulness of this map in policy and decision-making.